Weather Note

SURFACE PRESSURE OSCILLATIONS DURING A TYPHOON PASSAGE AT OKINAWA [1]

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Several quite large surface pressure oscillations were observed at Okinawa during the passage of typhoon Emma of 1956. These occurred within the eye of the typhoon and during the period of strong winds following the eye passage. Surface pressure oscillations in tropical cyclones have been studied by several investigators, especially Depperman [1] and Gherzi [2], but none of the cases in the literature, known to the writer, has shown fluctuations as large as those observed at Okinawa during typhoon Emma.

The oscillations to be considered in this note have fairly long periods (of the order of 20–40 min.) and are probably relatively rare. They are undoubtedly of quite different origin than the short-period "pumping" of the barometer which is fairly common during the periods of strong winds accompanying intense tropical cyclones.

The barogram from the Ryukyu Weather Bureau Observatory at Naha, Okinawa taken on September 8, 1956 (fig. 1), shows quite clearly the pronounced character of the pressure oscillations during typhoon Emma. The pressure varied as much as 7 mm. of Hg, or about 9 mb., between adjacent crests and troughs. The large oscillations began while the station was within the eye of the typhoon but were best developed when the wind speed was averging about 75 kt. with gusts to 125. The center of the storm passed about 20 mi. to the south of the station while moving toward the west-northwest at a speed of about 8 kt. The eye was quite large (about 60 mi. in diameter) and there was a considerable period of reduced wind speed associated with the eye passage. Speeds were less than typhoon force between 0415 and 0815 LST and reached a minimum of less than 30 kt. around 0630 LST. During this period the wind direction shifted gradually from east-northeast to southeast. The barograph trace was quite rough during the periods of strongest winds, indicating very-short-period oscillations. It is interesting that such oscillations were absent, or were greatly diminished in amplitude, while the wind was below typhoon force during the eye passage. The very slow increase in pressure following the passage of the eye over the station can be attributed, at least to some extent, to the fact that the typhoon was deepening. Dropsonde observations from a U.S. Air Force reconnaissance aircraft indicate that the central pressure decreased from 938 to 931 mb. between 0600 and 1200 LST.

[1] The research which led to the preparation of this note was supported by the U.S. Weather Bureau and the U.S. Navy Weather Research Facility.

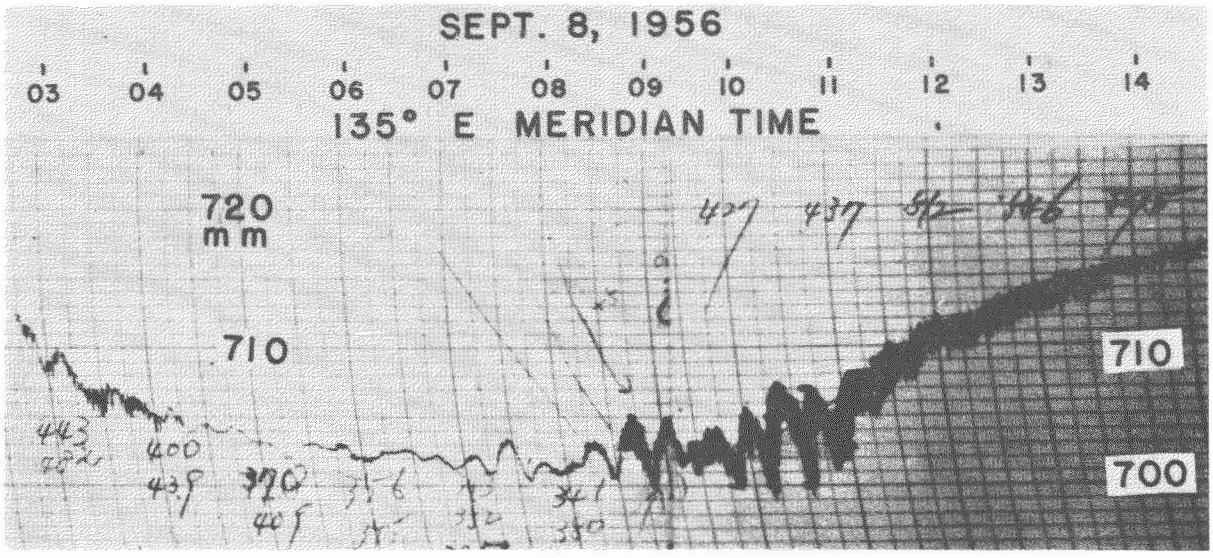

FIGURE 1.—Barogram from the Ryukyu Weather Bureau Observatory at Naha, Okinawa, taken during typhoon Emma of 1956. The handwritten figures are station and sea level pressures at hourly intervals expressed in millibars with the hundreds digit omitted. The chart was changed at approximately 0900 LST, and in piecing the records, account was taken of the fact that the barograph had been running fast by about 12 min.

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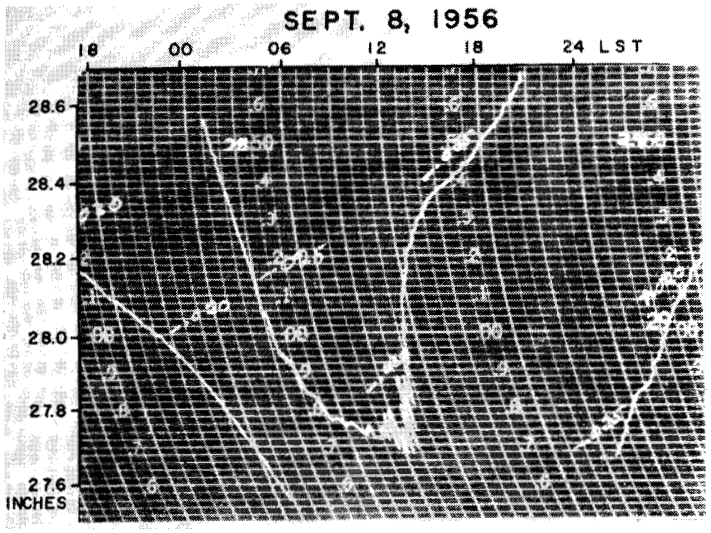

FIGURE 2.—Barogram from Naha AFB, Okinawa, during typhoon Emma of 1956. The pressure scale refers to the central portion of the curve; the values during the earlier and later portions are one inch of Hg higher than indicated by the scale. The station was within the eye of the typhoon from approximately 0400 through 0800 LST.

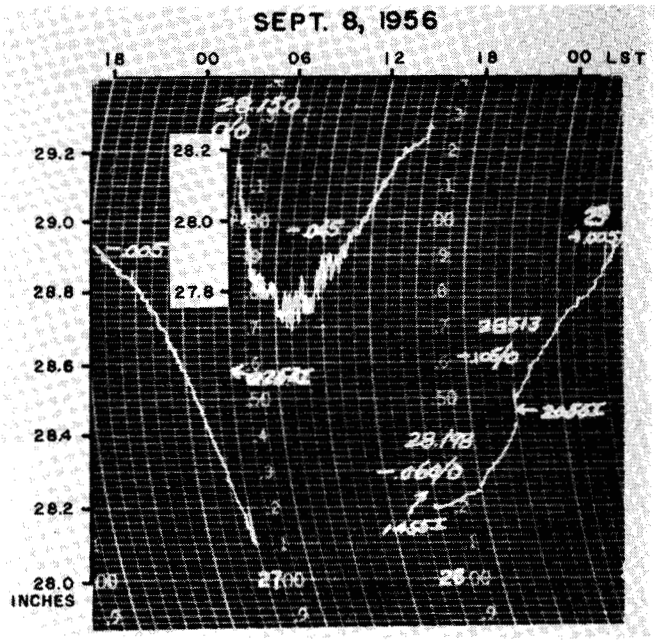

FIGURE 3.—Barogram from Kadena AFB, Okinawa, during typhoon Emma of 1956. Wind speeds were in excess of typhoon force from approximately 0600 LST through 1250 LST and during most of the period between 0300 and 0600 LST.

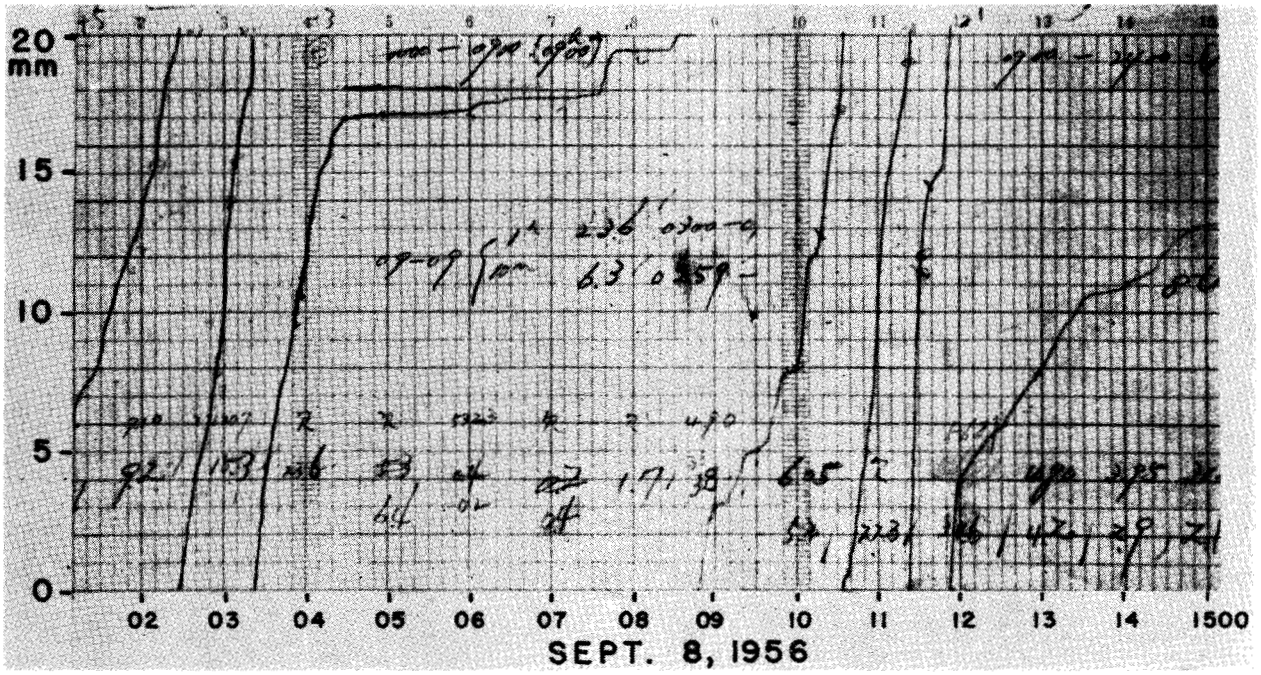

FIGURE 4.—A pluviograph record taken at the Ryukyu Weather Bureau Observatory during typhoon Emma of 1956. The rainfall rate is given by the slope of the curve Most of the handwritten figures are hourly rainfall totals (in mm.).

Barograms from two U.S. Air Force stations on Okinawa (figs. 2 and 3) show quite large oscillations during the same period as those noted at the Ryukyu Observatory. The periods of the oscillations seem to be about the same as those shown in figure 1 but the amplitudes are somewhat less. The maximum change between adjacent crests and troughs was about 0.18 in. of Hg, or about 6 mb. at Naha AFB and about 0.12 in. of Hg, or about 4 mb., at Kadena AFB. At Naha AFB, which was slightly closer to the center of the eye than the Ryukyu Observatory, the wind speed was reported as less than 20 kt. from about 0500 until 0800 LST. Kadena AFB, located about 10 mi. north-northeast of the Ryukyu Observatory, was never in the eye of the typhoon and wind speeds there were in excess of typhoon force throughout the period of relatively light winds at the other stations.

The rainfall curve for the Ryukyu Observatory taken during Emma (fig. 4) shows some interesting variations which appear to be associated in some way with the barometric oscillations. The rainfall was heavy prior to the arrival of the eye, especially from 0200 to 0430 LST, but the rate was relatively constant. The rainfall rate following the passage of the eye was quite variable, as can be seen by the markedly stepped character of the curve in figure 4. The weather observations from the Ryukyu Observatory listed light continuous rain throughout the period that the station was within the eye. The total rainfall during the period from 0430 to 0830 LST was about 3 mm. (0.12 in.) with more than half of this occurring during a 10-min. period near 0740 LST.

Rainfall rates and pressure values, read from figures 4 and 1 at 5-min. intervals, were plotted on the same diagram in an attempt to relate pressure and rainfall variations. The rainfall rate curve showed six oscillations between 0840 and 1110 LST with a period which ranged from 20 to 30 min. The pressure curve was difficult to specify during some portions of the record but seven major oscillations can be seen between 0805 and 1105 LST. There were also some fairly prominent fluctuations prior to this period. The period of the pressure oscillations varied from 20 to 40 min. but the average was also near 25 min. The phase of the rainfall rate and pressure curves varied considerably during the 3-hr. period but most of the periods of lighter rain occurred at or near the minimum points in the pressure curve and the heaviest rain tended to occur near the time of the peaks in the pressure curve. In view of the variability, little confidence can be placed in this suggested association; however, there is strong qualitative evidence that the rainfall variations are associated with the pressure variations. This is provided by the close correspondence in the average length of the period of the fluctuations in the two elements and by the fact that the rainfall rate was relatively steady except during the period when the pressure oscillations were present.

The only rainfall data for the Air Force stations on Okinawa are in the form of 6-hr. totals. It is of interest that extremely heavy rain was observed at Kadena AFB during typhoon Emma, with more than 30 in. reported between 0300 and 1500 LST on September 8 [3]. On the other hand, Naha AFB and the Ryukyu Observatory were within the eye during part of this period and their reported 12-hr. rainfall totals over the same period were both less than 6 in.

The wind records from the Ryukyu Observatory taken during Emma [4] were examined for evidence of periodic fluctuations but, even if present, these would be extremely difficult to resolve from the records. A sensitive Dines anemograph was used and the wind record showed speed variations of up to 70 kt. and direction variations in excess of 90° over periods of minutes. Wind recorders were not installed at the Air Force stations.

The time resolution on most barograph records is not great enough so that oscillations with periods of 20–30 min. can be clearly distinguished. However, there is little doubt that surface pressure fluctuations of the magnitude observed at Okinawa during typhoon Emma are very rare. None of the Philippine cases presented by Depperman [1] or the barograms for other typhoons affecting Okinawa during recent years show oscillations of the magnitude or duration of those shown in figure 1. Cases of pressure oscillations in hurricanes in recent years have also shown somewhat smaller amplitudes. Probably one of the most pronounced cases of these fluctuations in hurricanes is that observed at Mayaguana in the southeastern Bahamas during hurricane Donna of 1960 (fig. 5). Of course, in many cases the barograms taken during intense tropical cyclones show nothing in the way of periodic fluctuations and are, in fact, quite smooth; Dunn and Miller [5] show several examples of this type.

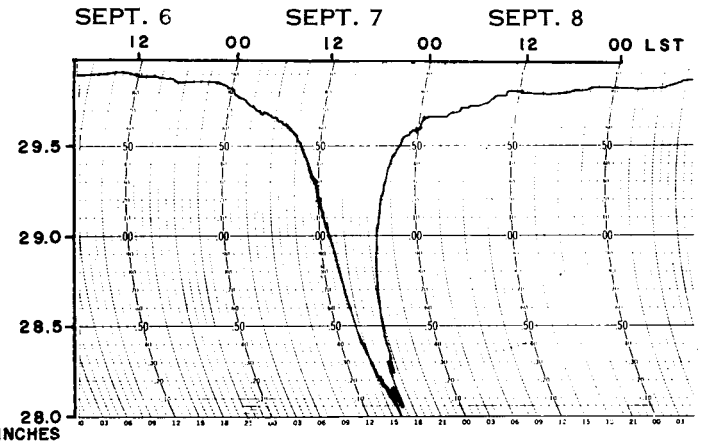

FIGURE 5.—Barogram from Mayaguana in the southeastern Bahamas during hurricane Donna of 1960. The station was not within the eye at any time but was probably as close as a mile or two to the edge of the eye at the time of lowest pressure.

No adequate explanation of the longer-period pressure oscillations in tropical cyclones has been provided but there has been some recent speculation on this subject. [6]

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REFERENCES

1. C. E. Depperman, *Some Characteristics of Philippine Typhoons,* Philippine Weather Bureau, Manila, P.I., 1939, 128 pp.
2. E. Gherzi, *The Meteorology of China,* Vol. II, Serviço Meteorológica, Província de Macao, Macao, 1951.
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4. Ryukyu Weather Bureau, *Report of Abnormal Weather,* No. 8, Naha, Okinawa, 1956, 54 pp. (in Japanese).
5. G. E. Dunn and B. I. Miller, *Atlantic Hurricanes,* Louisiana University Press, Baton Rouge, La., 1960, 326 pp.
6. C. L. Jordan, "Surface Pressure Oscillations in Tropical Cyclones," Paper presented at the Second Technical Conference on Hurricanes, Miami Beach, Florida, June 1961. (To be published in *National Hurricane Research Project Report* No. 50, March 1962.)